SEARCHING FOR HOT WHITE DWARFS

J. Allyn Smith
Austin Peay State University

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Fermilab

SEARCHING FOR HOT WHITE DWARFS

- What is a White Dwarf?
- Space Densities
- Atmospheric Models
- Search Techniques
- Surveys

What is a White Dwarf?

- White Dwarf 101
- Nomenclature
- Spectra
- Existing Catalogs

White Dwarf 101

- About 97% of all stars in the Universe will end their lives as white dwarfs.
- Progenitor stars are up to ~8$M_{\odot}$.
- The canonical WD is ~0.7$M_{\odot}$, but can range from ~0.25-1.41$M_{\odot}$.
- Radius is about 0.01$R_{\odot}$ (size of the Earth).
- Most have a surface gravity of log(g)~8, but can range from log(g) ~7-9.

White Dwarf 101

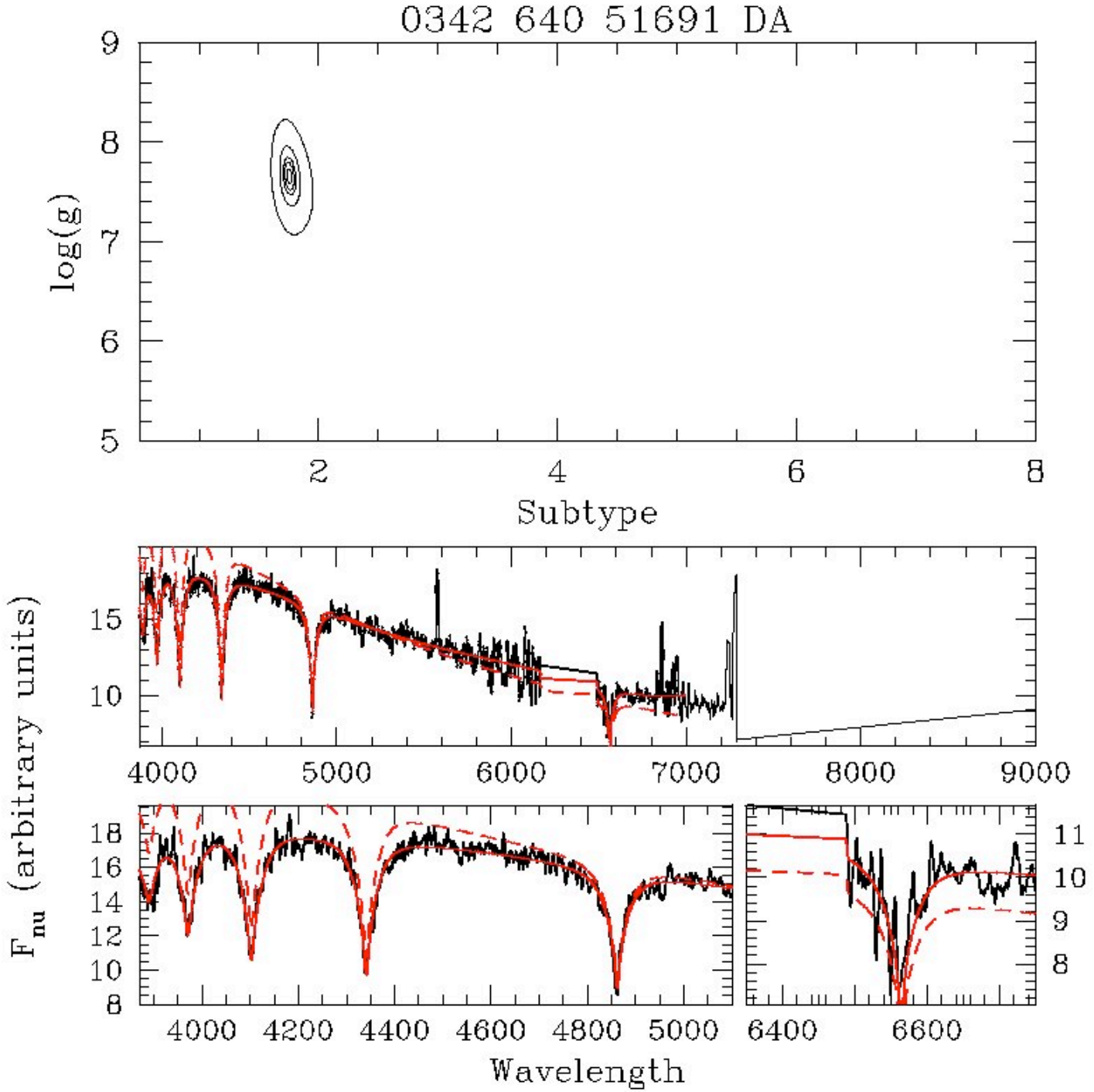
- Temps range from ~150,000--> ~3300K.
- A fast calculation:
  - For a T=5800K WD (solar temp)
  - R^2T^4 ==> 0.0001 $L_\odot$ (M_V ~ 14.4 at 10 pc)
    - or ~19.4 at 100 pc.
  - So, these stars are generally “faint” and nearby.

White Dwarf 101

- The cores are generally C/O though other cores are known. Crystallization is important in the cooler stars.
- Except for a thin non-degenerate layer of the atmosphere, the rest of the star is electron degenerate matter.
- Atmospheres are generally H or He, some with trace elements.
- It is the non-degenerate layer which we observe and which controls radiative loss rates.

White Dwarf 101

- Determine physical properties via line fits in medium-high resolution spectra. Wings of the lines are extremely sensitive to the surface gravity. Depth and width of lines are sensitive to temperature and H layer thickness.


0342 640 51691 DA
log(g)
Subtype
F_{nu} (arbitrary units)
Wavelength

Nomenclature

- **Sion, Greenstein, Landstreet, Liebert, Shipman, Wegner 1983 ApJ, 269, 253**
- White dwarf spectral types all start with a “D” for “degenerate”.
- **Primary and secondary features**
- A H lines present; no He I or metal lines
- B He I lines; no H or metal lines
- C Continuous spectrum; no lines
- O He II lines, accompanied by He I or H lines
- Z Metal lines; no H or He I lines
- Q Carbon lines present
- X Unclear or unclassifiable spectrum
- # is a temperature indicator = 50,400/Temp
- **Secondary features only**
- P Magnetic white dwarf with detectable polarization
- H Magnetic white dwarf without detectable polarization
- E Emission lines present
- V Variable
- Examples: DA4 or DABZH

Spectra

DA, DAH, DAE

DB

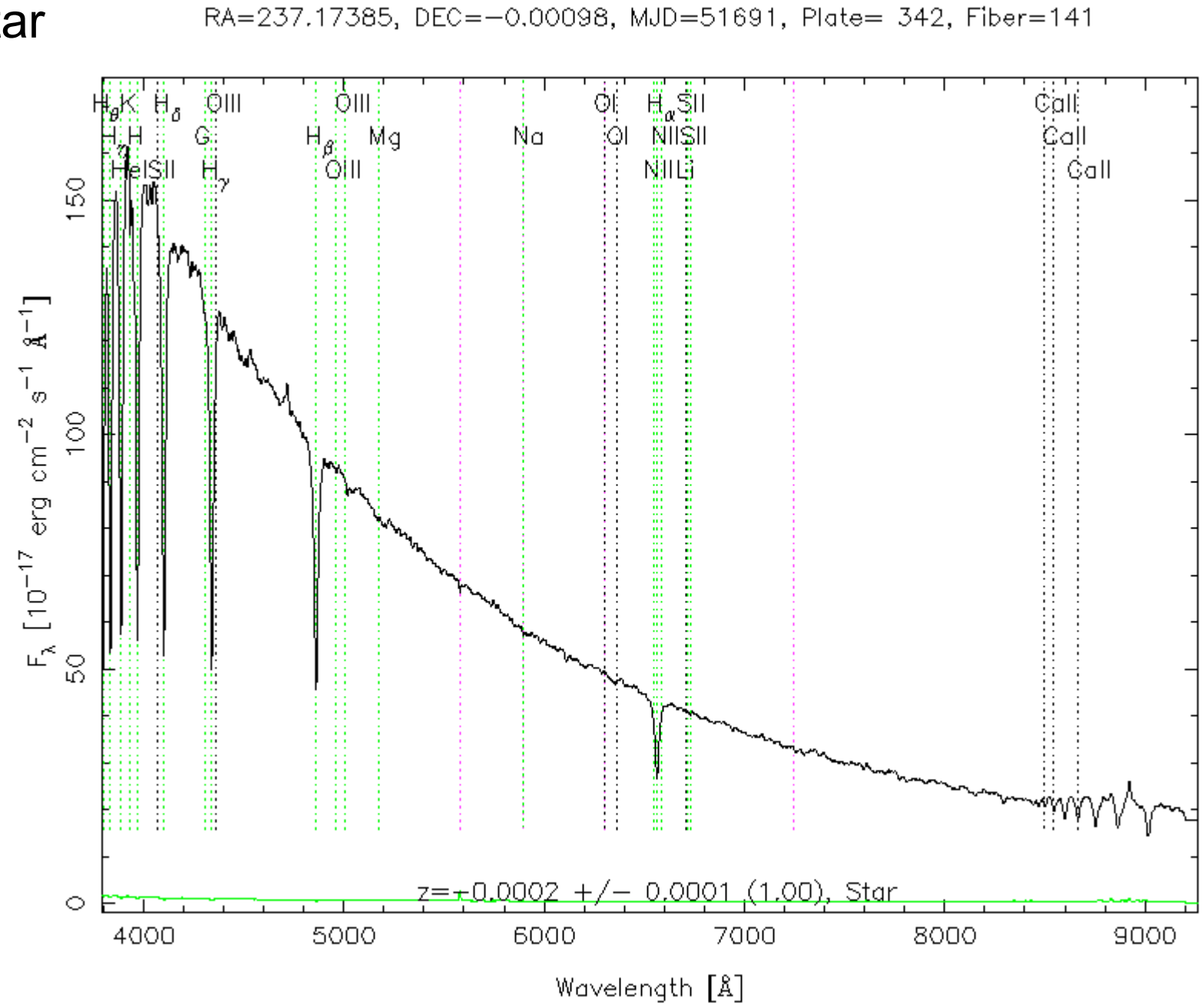
DO

DC

DZ

DQ

A star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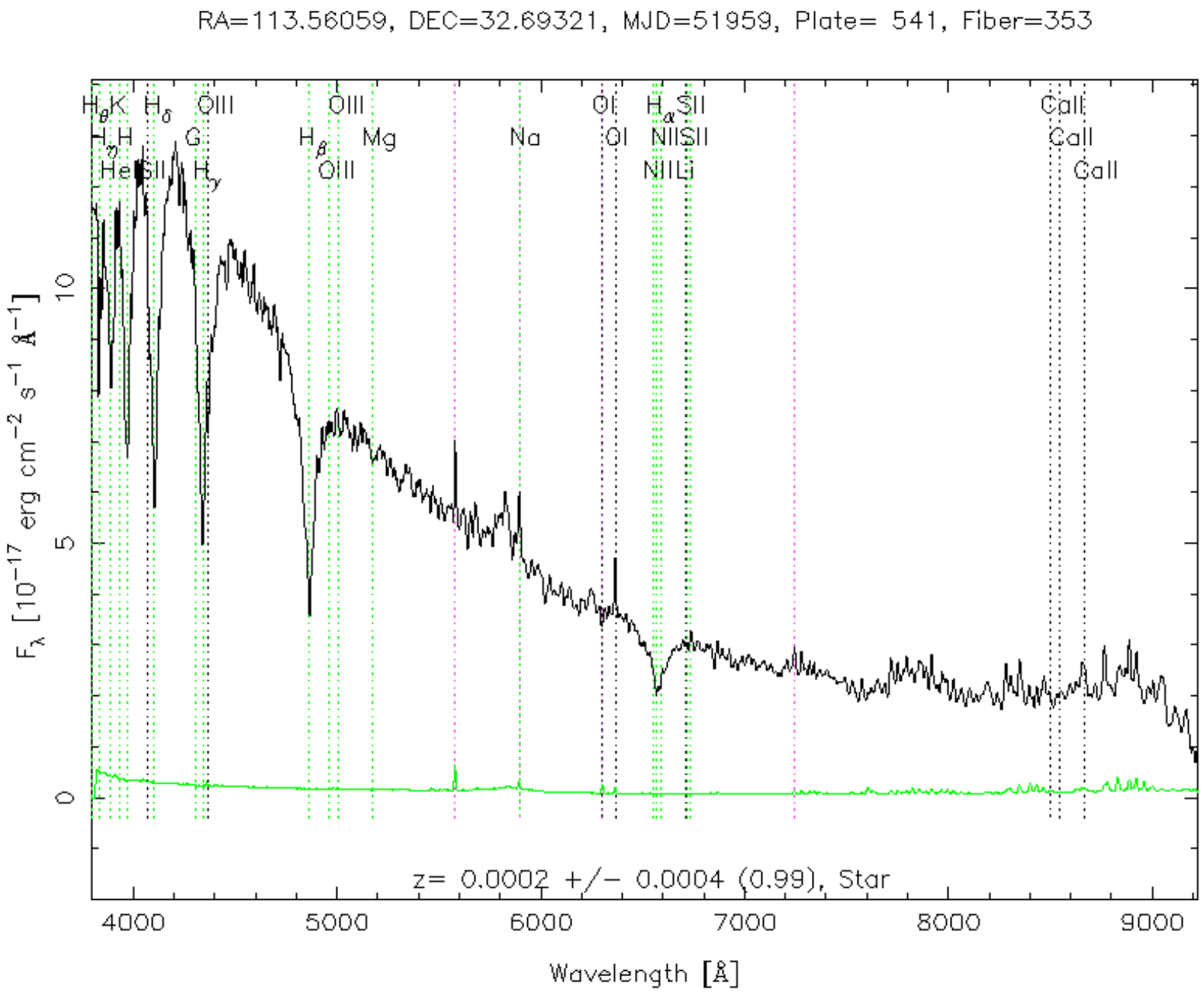
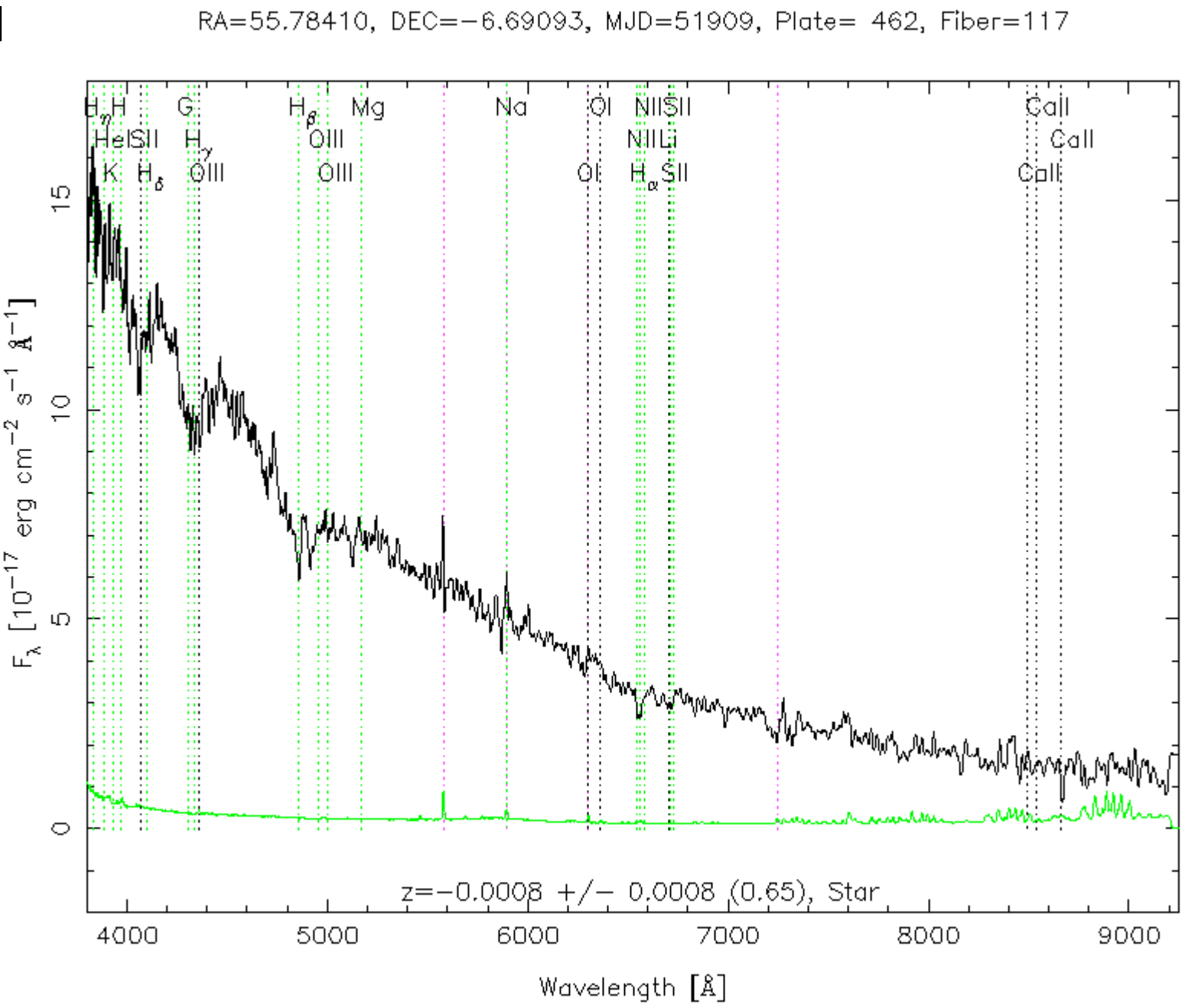
H8
K
Hδ
OIII
OIII
OI
Hα
SII
CaII
H
G
Hβ
Mg
Na
OI
NII
SII
CaII
HeI
SII
Hγ
OIII
NII
CaII
z=+0.0002 +/− 0.0001 (1.00), Star
F_λ [10^−17 erg cm^−2 s^−1 Å^−1]
0
50
100
150
4000
5000
6000
7000
8000
9000
Wavelength [Å]

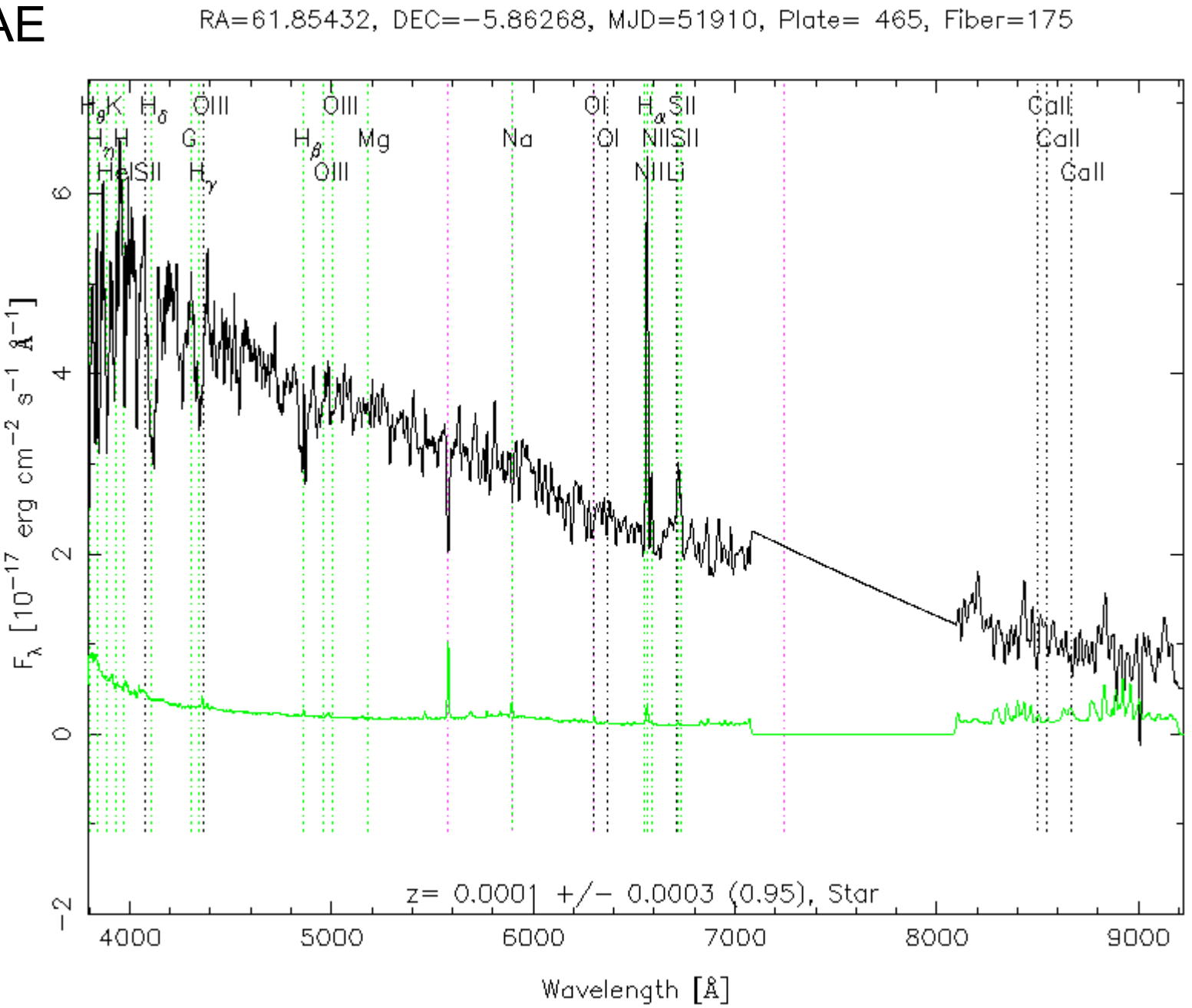
DA


RA=113.56059, DEC=32.69321, MJD=51959, Plate= 541, Fiber=353
H$_\theta$
K
H$_\delta$
OIII
OIII
OI
H$_\alpha$
SII
CaII
H$_9$
H
G
H$_\beta$
Mg
Na
OI
NII
SII
CaII
HeI
SII
H$_\gamma$
OIII
NII
L
CaII
F$_\lambda$ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
5
10
z= 0.0002 +/- 0.0004 (0.99), Star
4000
5000
6000
7000
8000
9000
Wavelength [Å]

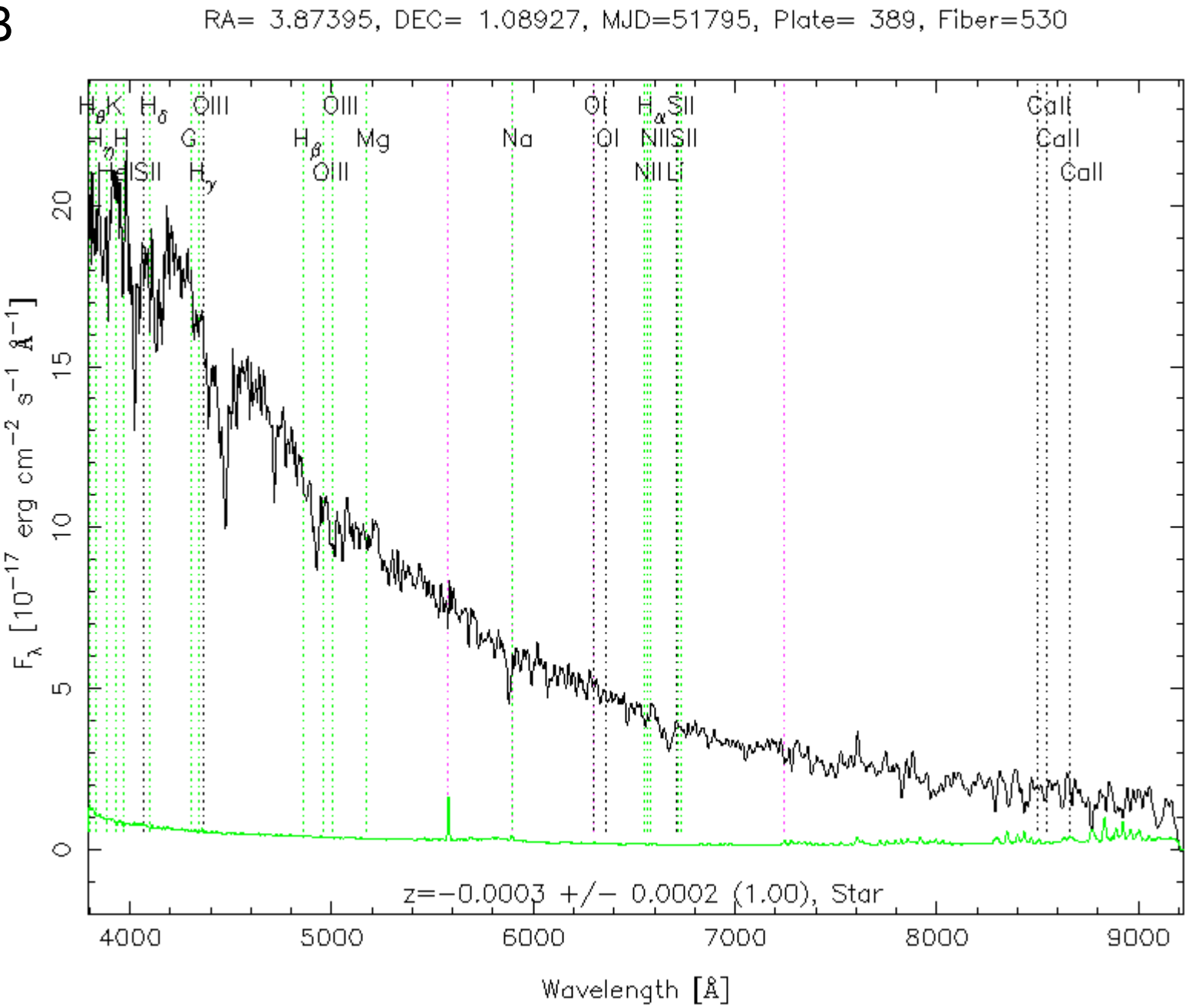
DAH


RA=55.78410, DEC=−6.69093, MJD=51909, Plate= 462, Fiber=117
H$_\epsilon$
H
HeI
SII
K
H$_\delta$
G
H$_\gamma$
OIII
H$_\beta$
OIII
OIII
Mg
Na
OI
OI
NII
SII
NII
Li
H$_\alpha$
SII
CaII
CaII
CaII
F$_\lambda$ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
5
10
15
z=−0.0008 +/− 0.0008 (0.65), Star
4000
5000
6000
7000
8000
9000
Wavelength [Å]

DAE


RA=61.85432, DEC=−5.86268, MJD=51910, Plate= 465, Fiber=175
H9
K
Hδ
OIII
OIII
OI
Hα
SII
CaII
H
G
Hβ
Mg
Na
OI
NII
SII
CaII
H
SII
Hγ
OIII
NII
G
CaII
z= 0.0001 +/− 0.0003 (0.95), Star
Fλ [10−17 erg cm−2 s−1 Å−1]
Wavelength [Å]
−2
0
2
4
6
4000
5000
6000
7000
8000
9000

DB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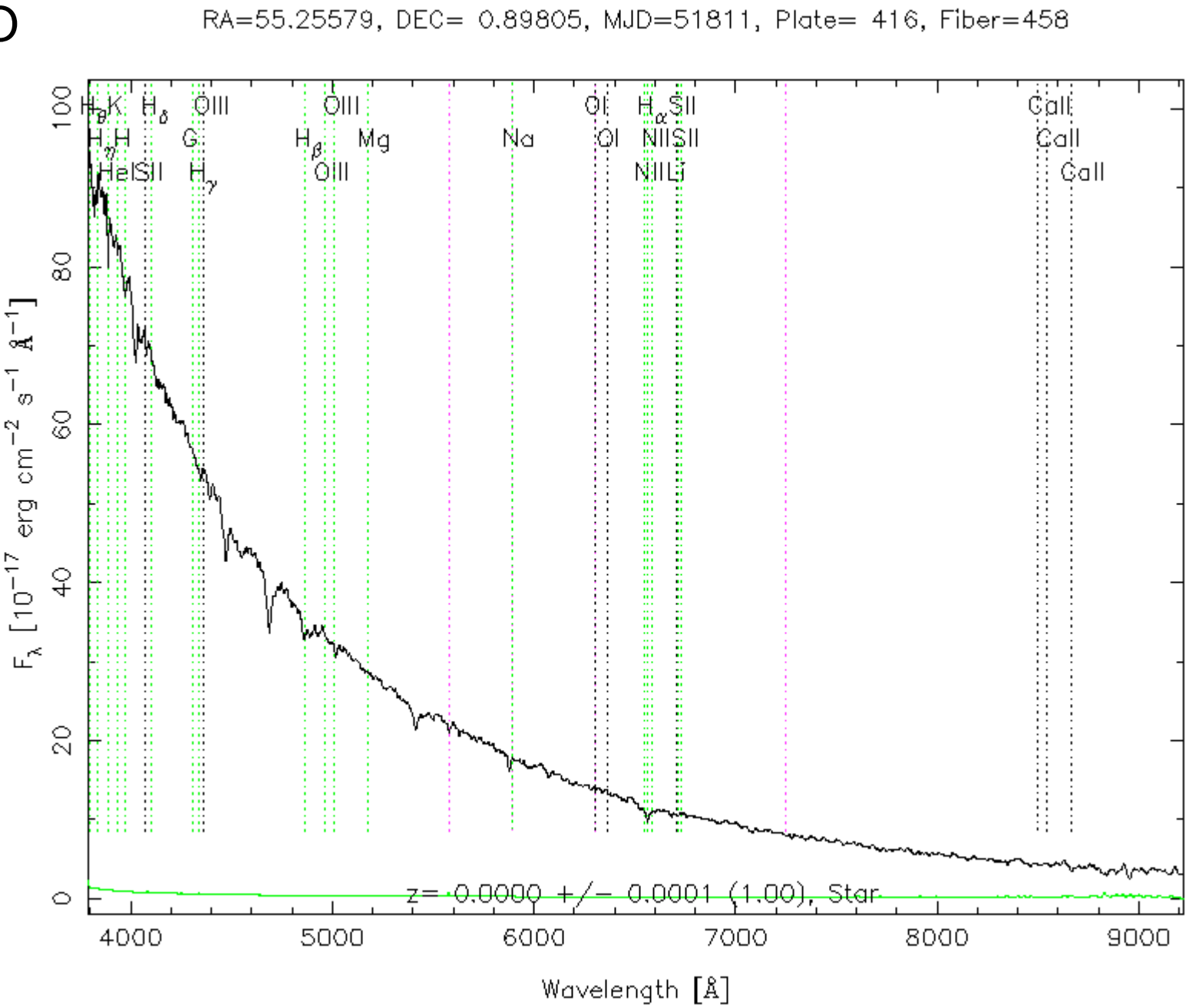
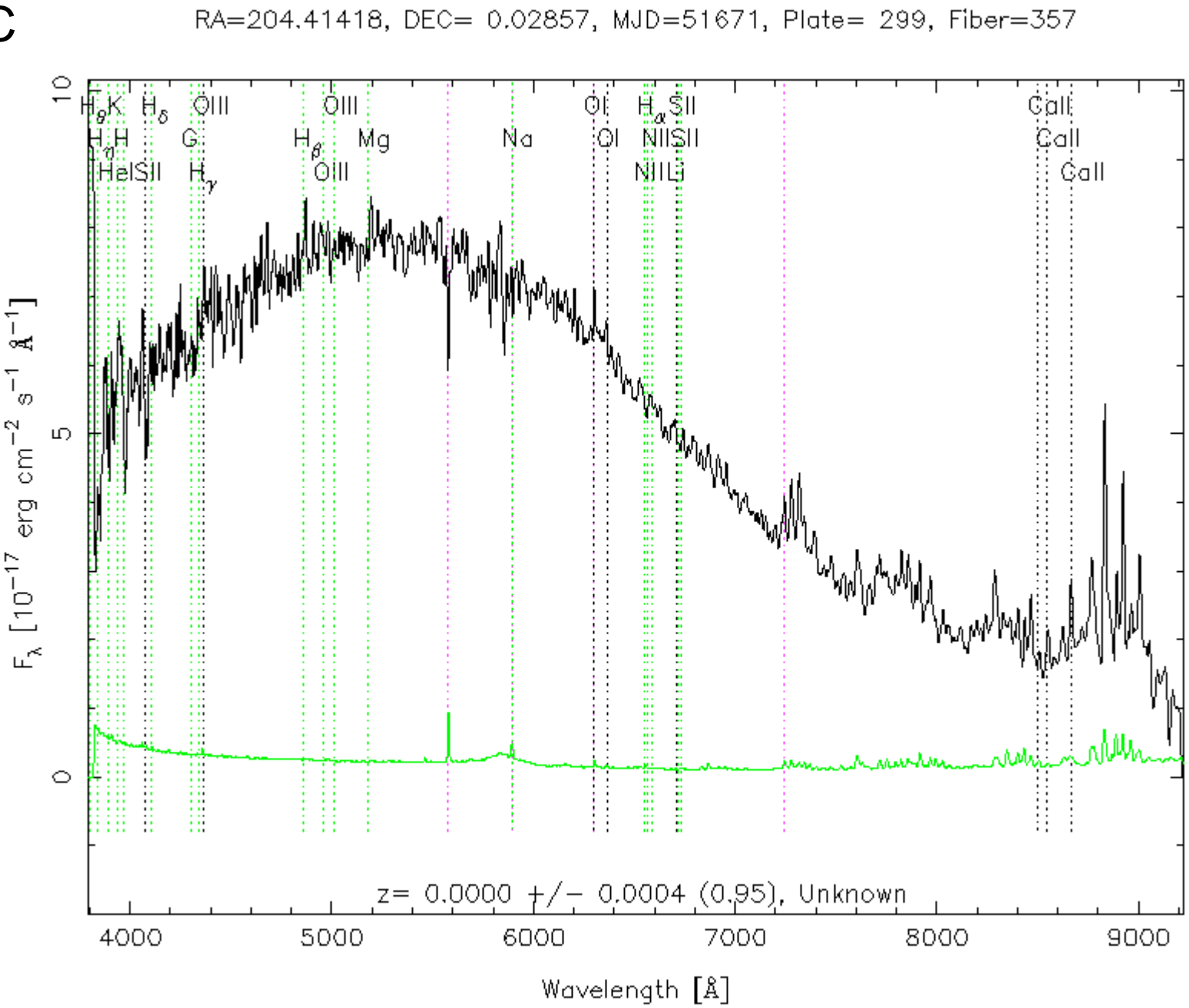
H$_\theta$
K
H$_\delta$
OIII
H$_\beta$
OIII
OI
H$_\alpha$
SII
CaII
H$_\epsilon$
H
G
Mg
Na
OI
NII
SII
CaII
SII
H$_\gamma$
OIII
NII
CaII
F$_\lambda$ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
5
10
15
20
z=−0.0003 +/− 0.0002 (1.00), Star
4000
5000
6000
7000
8000
9000
Wavelength [Å]

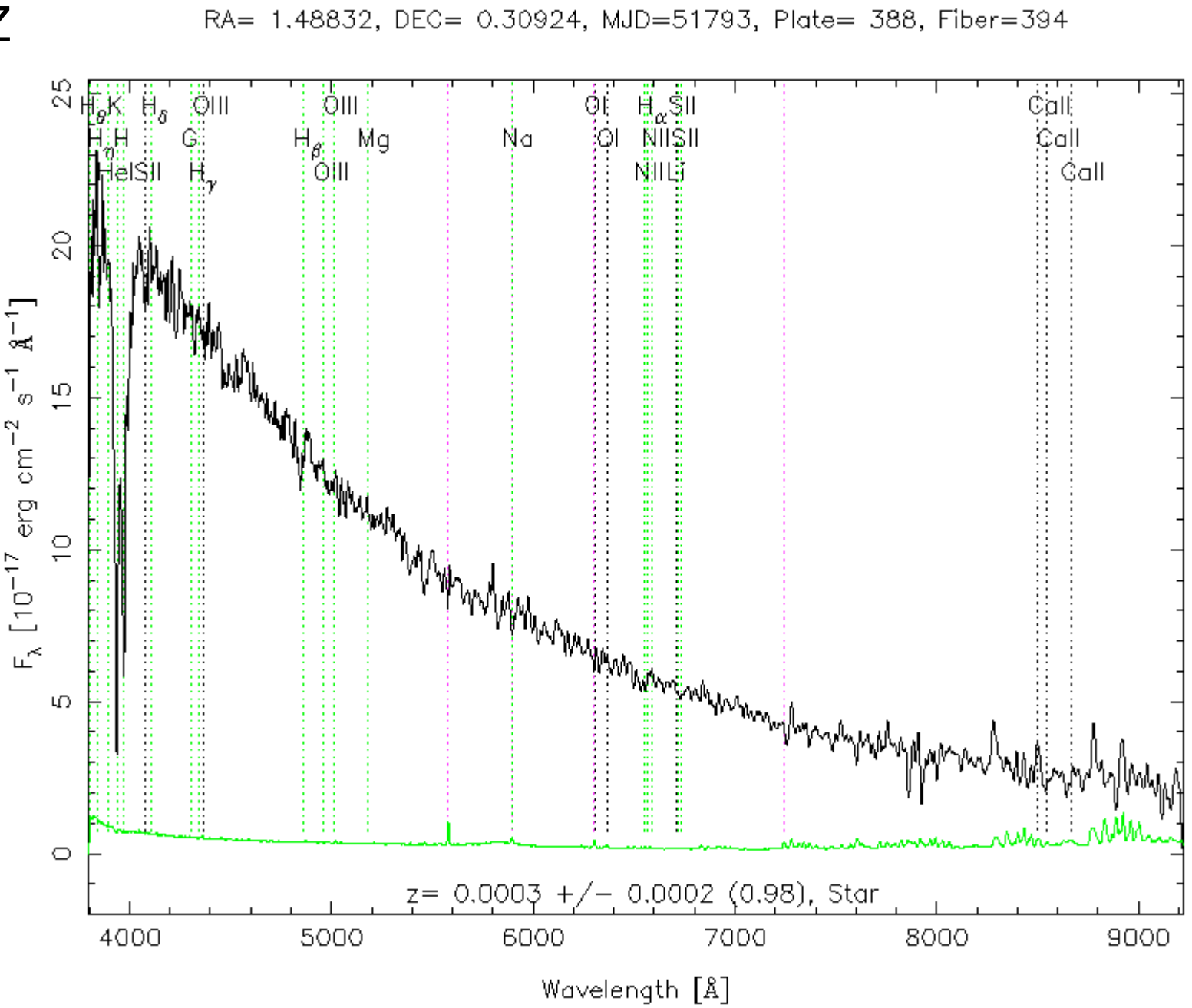
DO


RA=55.25579, DEC= 0.89805, MJD=51811, Plate= 416, Fiber=458
H$_\theta$
K
H$_\delta$
OIII
H$_\zeta$
H
G
H$_\beta$
OIII
Mg
Na
OI
H$_\alpha$
SII
CaII
HeI
SII
H$_\gamma$
OIII
OI
NII
SII
CaII
NII
CaII
z= 0.0000 +/- 0.0001 (1.00), Star
F$_\lambda$ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
20
40
60
80
100
4000
5000
6000
7000
8000
9000
Wavelength [Å]

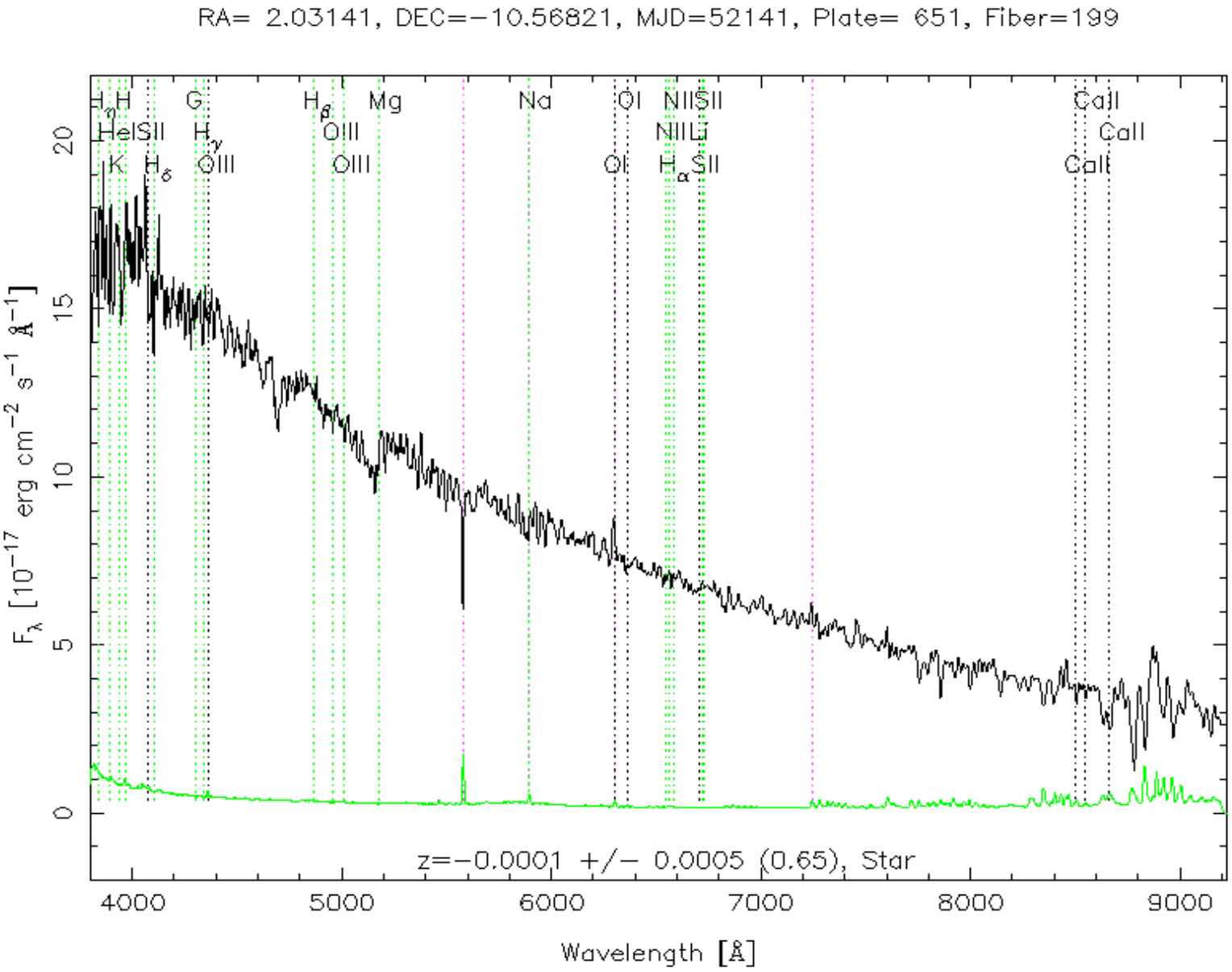
DC


RA=204.41418, DEC= 0.02857, MJD=51671, Plate= 299, Fiber=357
H$_\epsilon$ K H$_\delta$ OIII
H$_\eta$ H G
HeI SII H$_\gamma$
H$_\beta$ OIII
OIII Mg
OIII
Na
OI NII
OI SII
H$_\alpha$ NII SII
CaII
CaII
CaII
z= 0.0000 +/- 0.0004 (0.95), Unknown
F$_\lambda$ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
5
10
4000
5000
6000
7000
8000
9000
Wavelength [Å]

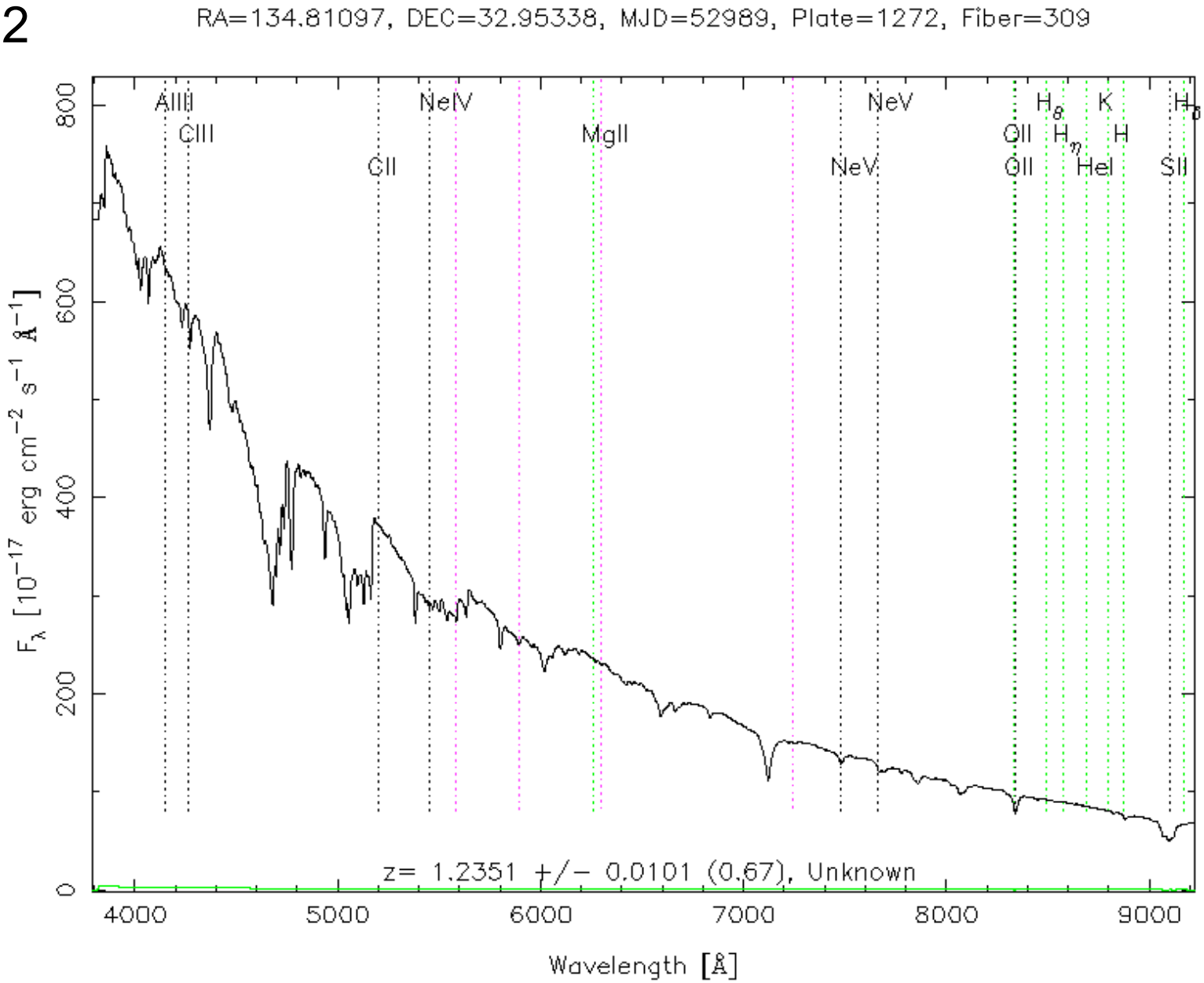
DZ


RA= 1.48832, DEC= 0.30924, MJD=51793, Plate= 388, Fiber=394
H$_\epsilon$
K
H$_\delta$
OIII
OIII
OI
H$_\alpha$
SII
CaII
H
H$_\eta$
G
H$_\beta$
Mg
Na
OI
NII
SII
CaII
HeI
SII
H$_\gamma$
OIII
NII
Li
CaII
F$_\lambda$ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
5
10
15
20
25
z= 0.0003 +/- 0.0002 (0.98), Star
4000
5000
6000
7000
8000
9000
Wavelength [Å]

DQ


RA= 2.03141, DEC=−10.56821, MJD=52141, Plate= 651, Fiber=199
H
G
Hβ
Mg
Na
OI
NII
SII
CaII
HeI
SII
Hγ
OIII
OIII
NIII
Li
CaII
K
Hδ
OIII
OI
Hα
SII
CaII
F_λ [10^−17 erg cm^−2 s^−1 Å^−1]
0
5
10
15
20
z=−0.0001 +/− 0.0005 (0.65), Star
4000
5000
6000
7000
8000
9000
Wavelength [Å]

DQ2


RA=134.81097, DEC=32.95338, MJD=52989, Plate=1272, Fiber=309
AlIII
CIII
CII
NeIV
MgII
NeV
NeV
OII
OII
H_δ
H_η
HeI
K
H
H_ϵ
SII
z= 1.2351 +/- 0.0101 (0.67), Unknown
F_λ [10^{-17} erg cm^{-2} s^{-1} Å^{-1}]
0
200
400
600
800
4000
5000
6000
7000
8000
9000
Wavelength [Å]

Existing Catalogs/DB

- **McCook-Sion White Dwarf Catalog**
  http://heasarc.nasa.gov/W3Browse/all/mcksion.html
- **SDSS DR1 and DR4**

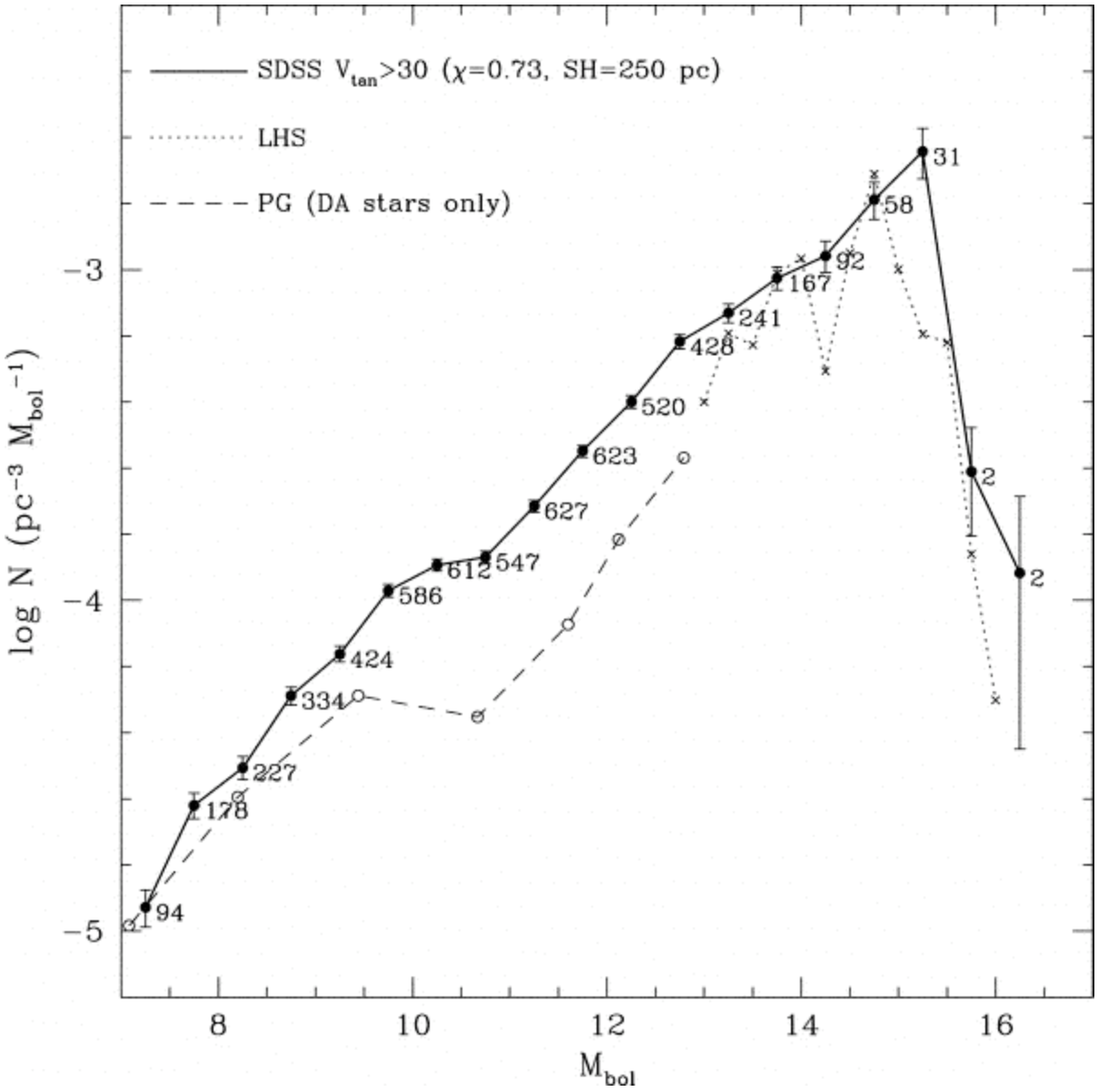
  http://www.sdss.org/dr6/products/value_added/index.html
- **Jay Holberg -U. Az. - Under Construction**

  http://procyon.lpl.arizona.edu/WD/

Space Densities

- Liebert, Dahn, Monet 1988, ApJ, 332, 891
  - 42 stars, 0.003/pc^3
- Oswalt, Smith, Wood, Hintzen 1996, Nature, 382, 692
  - 69 stars, ~0.007/pc^3
- Smith, 1997, Ph.D. thesis
  - 152 stars, 0.0045/pc^3 , 4.65x10^{-13}/yr/pc^3 birthrate
  - first volume based corrections for missing stars
- Harris, et al. 2006, AJ, 131, 571 (SDSS DR3)
  - 6000 stars, 0.0046/pc^3, 4x10^{-5}/pc^3 in the Halo
  - First definitive Halo LF, solved contamination issues,
  - Scale height determinations.

WDLF


SDSS V_{tan}>30 (χ=0.73, SH=250 pc)
LHS
PG (DA stars only)
log N (pc^{-3} M$_{bol}^{-1}$)
M$_{bol}$
−3
−4
−5
8
10
12
14
16
94
178
227
334
424
586
612
547
627
623
520
428
241
167
92
58
31
2
2

Space Densities

- Jay Holberg will show a plot later of expected numbers by galactic latitude.

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- Atmospheric Models
- Search Techniques
- Surveys

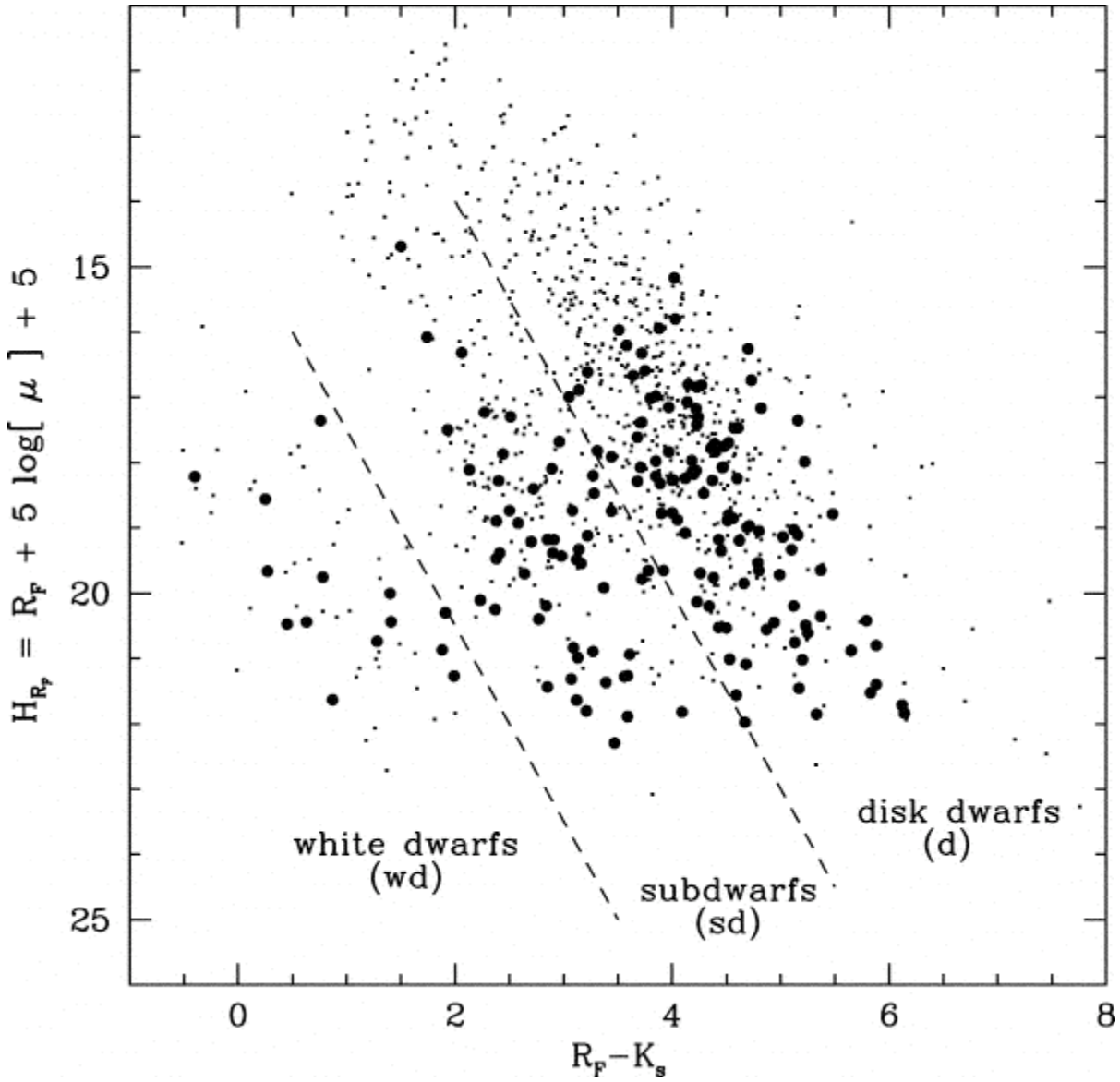
Atmospheric Models

- Pierre Bergeron, University of Montreal
- Hubeny & Lanz 1995, ApJ, 439, 875

Search Techniques

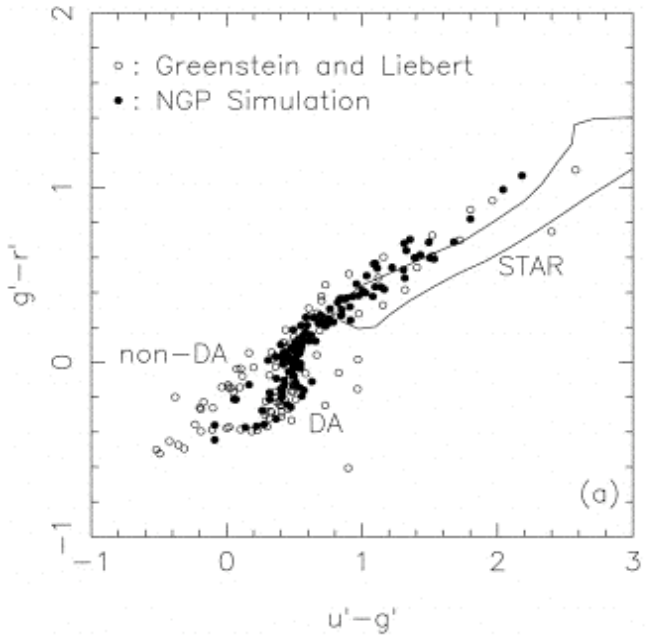
- Use of Reduced Proper Motion plots.
- Unique color-color space for the right filters.
- DDO-51 filter survey – centered on MgH band

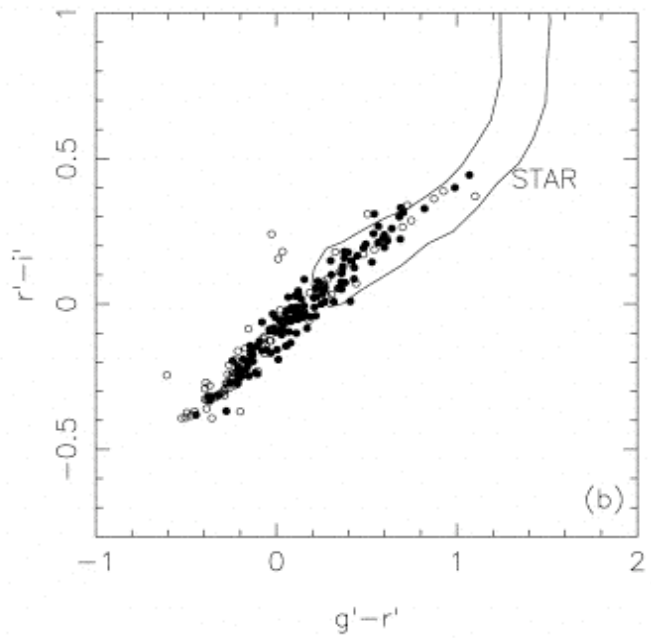
RPM

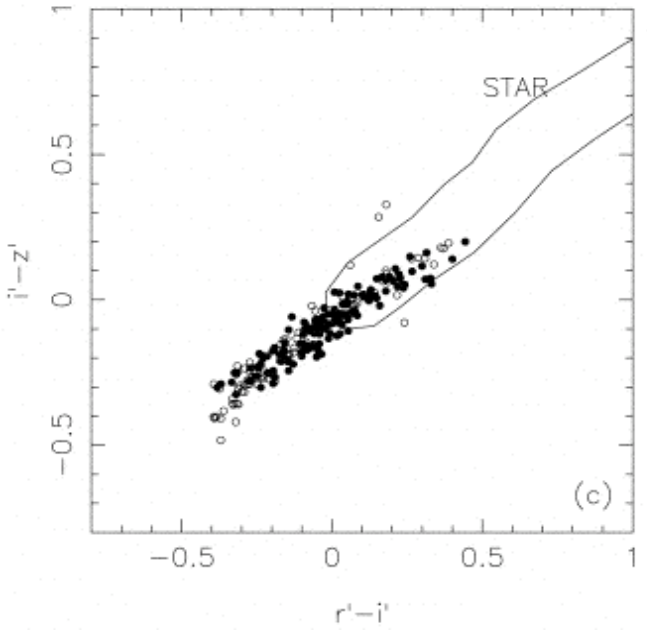


Lepine 2005 AJ 130, 1247

Color Space

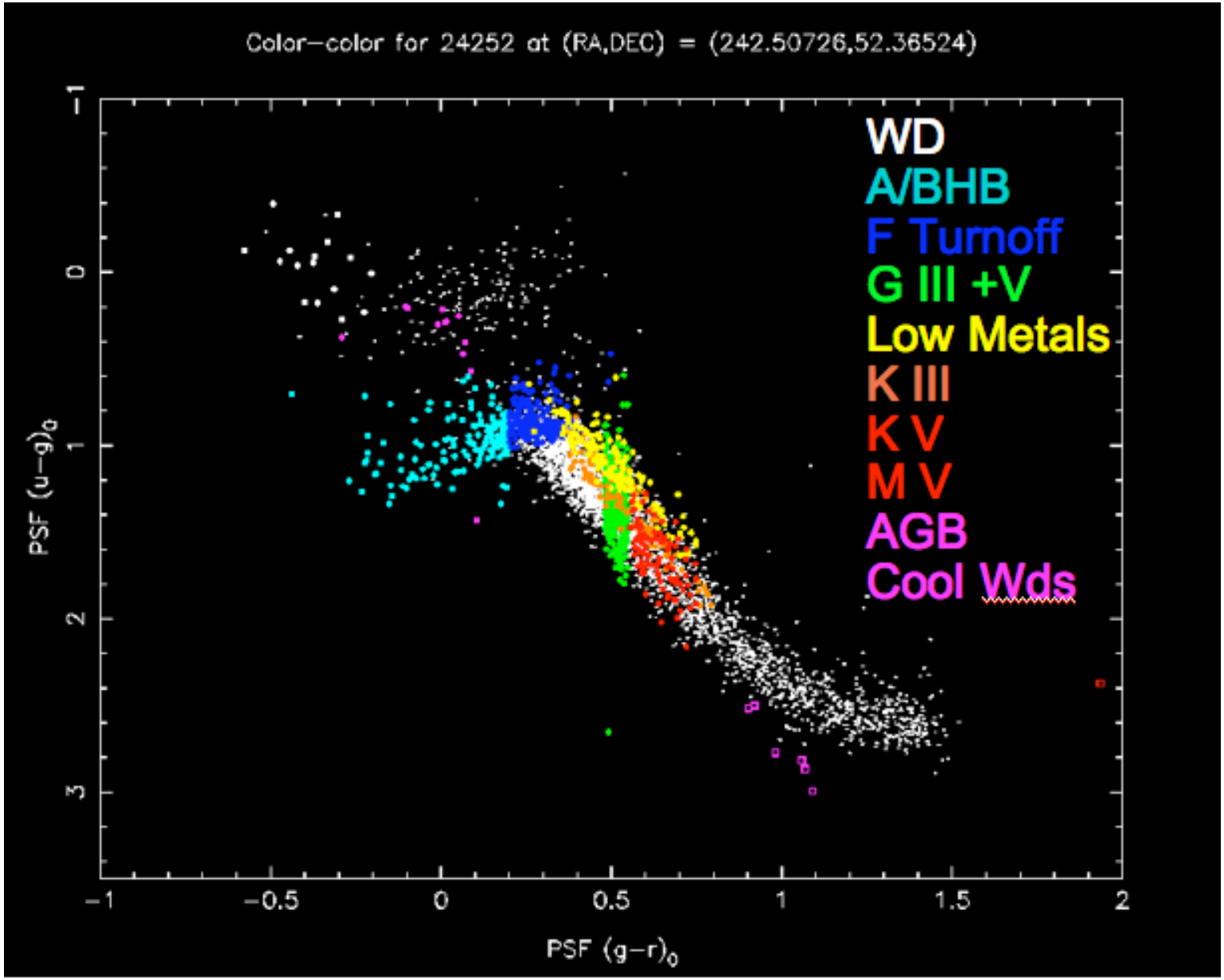






Fan 1999 AJ, 117, 2528

Color Space



SEGUE target selection, courtesy Brian Yanny

Complications

- Hard to determine Bolometric Corrections from broad band photometry alone.
- Unresolved companions (substellar, dust shells...)
  - could be as high as 10-15% (or more)
- Undetected He in atmosphere of a DA ... requires JHK photometry to sort out – more of a problem with cool Wds.
- magnetic fields